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The Use of Pregerminated Seed in Bare Root Transplant Production

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A technique was developed whereby seed was pregerminated in sphagnum moss cigarette plugs. These were then planted into peat cubes in the greenhouse prior to transplanting in nursery beds. Two-year-old bare root transplants from this system met OMNR 3+0 standards for height and root collar diameter provided seed was sown prior to May 1. The potential application in provincial stock production is discussed.

INTRODUCTION

In the production of bare root nursery stock from Ontario provincial nurseries, seed efficiency, defined as the proportion of trees shipped relative to viable seed sown, is low (Table 1). Low seed efficiency indicates heavy losses over the duration of stock production. Though losses vary between nurseries, for the 5 major conifers representing 90% of Ontario's planting program they average approximately 60% for bed-sown jack pine *(Pinus banksiana Lamb.)*, 75% for red pine *(Pinus resinosa Ait.)*, white pine *(Pinus strobus L.)* and white spruce *(Picea glauca (Moench) Voss)*, and over 80% for black spruce *(Picea mariana (Mill.) B.S.P.)*.

Losses are due to many factors. Under optimum laboratory conditions, most black spruce germination occurs within four to ten days. Inventory data through the 1+0 year on provincial nurseries indicate that germination in seed beds is much lower and occurs over a long time span. The result is variable germination time.

Emergence is also a serious problem, especially for small seeded species such as black spruce, because of low initial vigor. Germination is restricted by soil cover exceeding 2 mm (Carmichael 1968), whereas normal sowing depths in nursery beds vary up to 1.2 cm. Movement of soil due to wind and irrigation and movement of seed due to percolation in cracks that develop overwinter along drill lines, result in variable depths of seed at time of germination in the spring.

The resultant small seedlings often have inadequately developed root systems and are therefore susceptible to frost heaving in the fall and following spring. This can result in the loss of numerous seedlings if snow cover arrives late or melts early. Many of the remaining partially heaved seedlings exhibit abnormal stem and root form in the second year.

Physical damage and other defects necessitating culling are only partially influenced by seed. Irregular survival results in uneven spacing between trees in the bed, making separation without root damage difficult.

Collection considerations make it necessary to improve the effective use of seed. Though collection cost is not a major factor in the cost of established plantations, it is becoming increasingly difficult to find adequate labour to provide the quantities of seed required.

Provincial policy is directed toward improving the quality of seed collected. It has been recommended that by 1985 80% of all provincial

TABLE 1 Seed efficiency in Ontario provincial nurseries expressed as percentage of bare root nursery stock shipped relative to viable seed sown, based on germination sand tests

Species	Red pine		White pine			Jack pine		White spruce				Black spruce			
Age class	2+0	3+0	3+0	1+2	2+2	2+0	3+0	3+0	1+2	1½+1½	2+2	3+0	1+2	1½+1½	2+2
Southern Ontario															
Kemptville	25	27	24			42		23	28			22			
Midhurst		34			24	30		28							
Orono		25	28		21	31		28			25				
St. Williams		25	25			27		14		17					
Northern Ontario															
Dryden		27				42				21	18	13		14	13
Thunder Bay		38			25	45		16		20	20	9		12	
Swastika				28		50					30	29	27		
Chapleau			33				51								
Thessalon		43	42			37		28				29			

seed collections should come from selected and improved sources (Armson 1976). If genetic improvements are to be effective in providing the gains expected, it is important to develop stock production methodology which optimizes seed efficiency.

One approach is the investigation of pregermination systems. Hand planting of germinants has long been practised in areas of the developing world where labour costs are low (Fig. 1). Hagner[1] developed a system of germinating and holding seed until sowing in an effort to achieve initial stocking of 100% in a thirty-five million tree multipot greenhouse operation in Sundsvall, Sweden. Though their seed efficiency resulted in 90% success, the estimated loss from 10% empty containers was approximately $140 000.

Scientists in Britain have worked with ethylene glycol as a pregermination medium allowing initial imbibition of moisture to a state of germination readiness. Fluid drilling of pregerminated seed is now an operational technique marketed in Britain (Anon., undated).

Any form of improvement in seed efficiency will reduce collection workload and maximize area planted from genetically improved collections. To achieve these goals a system is being developed that will effect a high rate of seed efficiency and ensure close to full stocking in greenhouse facilities; subsequent precision transplanting results in more uniform stock.

Figure 1 Pricking out....handplanting of germinants in a Kenyan nursery.

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[1]Personal communication, Dr. Mats Hagner, Department of Forestry, University of Umeå, Sweden, July 1975.

This will eliminate or reduce the cost of culling and reduce stock production time. Developmental steps and preliminary findings are discussed in this report.

DEVELOPMENTS

To date, methods and equipment as described here have been developed to facilitate research operations. Ultimately it is intended to automate each operation to minimize labour input.

Germination Plugs

A pregermination system was required to provide protection for the delicate developing radicle. A mini-container was an obvious means of handling the radicle even in an automated process. Waxed paper straws were considered but proved difficult to fill with a germinating medium. Cotton dental rolls (Fig. 2) proved excellent for germination but were difficult for radicle penetration and for maintaining a suitable moisture content.

The material eventually chosen consisted of sphagnum with a methocel binder, in the form of cigarettes. Initially these were rolled by hand using gauze bandage stiffened with a gelva spray for 'paper'. The sphagnum cigarettes were cut to 1.5 cm lengths and placed in predrilled plastic foam plates at a spacing to allow sowing with a tubed seedling vacuum seeder head (Williamson 1964).

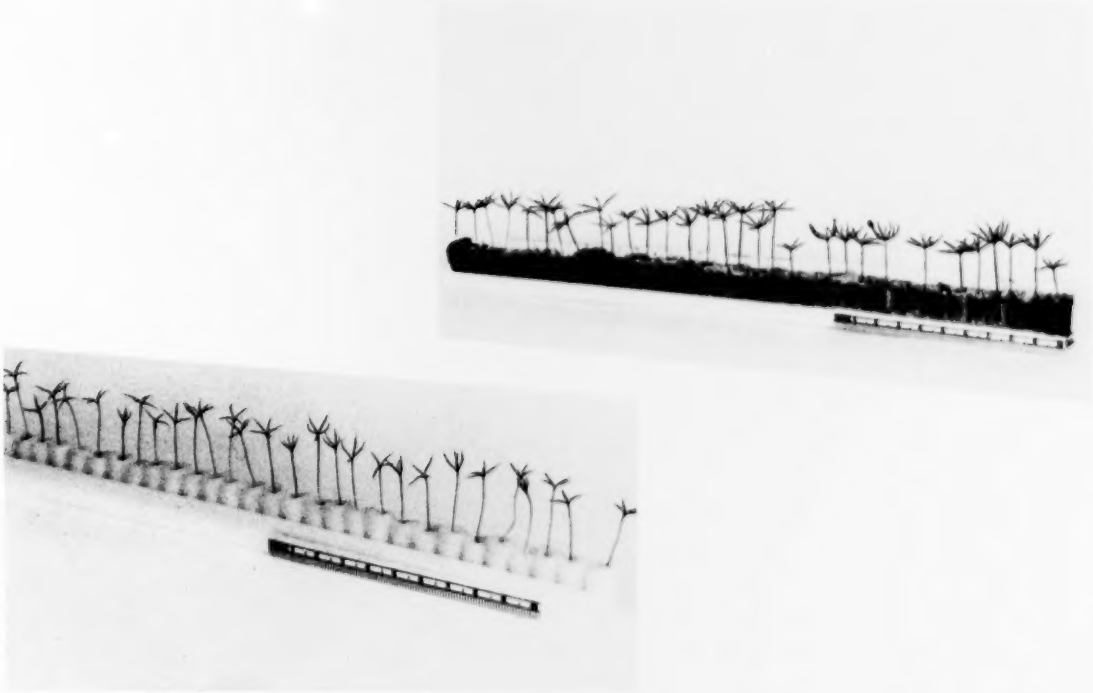

Figure 2 Troughs of germinants in pregermination plugs of rolled cotton (lower) and sphagnum cigarettes (upper).

Subsequent developments have included modification of a standard cigarette machine using cleaned sphagnum moss rolled in a gauze material similar to that used for tea bags. The machine produces 800 cigarettes, 9.0 cm in length, per minute. Cigarettes are handled in 30 cm lines, using clamps to control the line while plugs are cut to 1.5 cm lengths (Fig. 3) and placed into a plastic trough-shaped container. The line of plugs is seeded with a single line vacuum seeder head.

Growing System

Germinants develop to cotyledonous seedlings in plugs but must be planted into a greenhouse growing system. An agricultural machine for producing soil cubes (Fig. 4) was selected. To meet forestry needs it was adapted to cut cubes with a surface 2.5 cm square, providing 1600/m^2 in a continuous production line 30 cm wide (Fig. 5). The machine was further modified to provide dibble holes of sufficient depth to accommodate a germination plug in each cube rather than the shallow depressions formed by the standard model for sowing seed.

Greenhouses

Duration of initial growth in the greenhouse was one of the first aspects to be investigated. Standard greenhouse conditions and procedures were used in this study at Maple but optimum prescriptions are still to be determined.

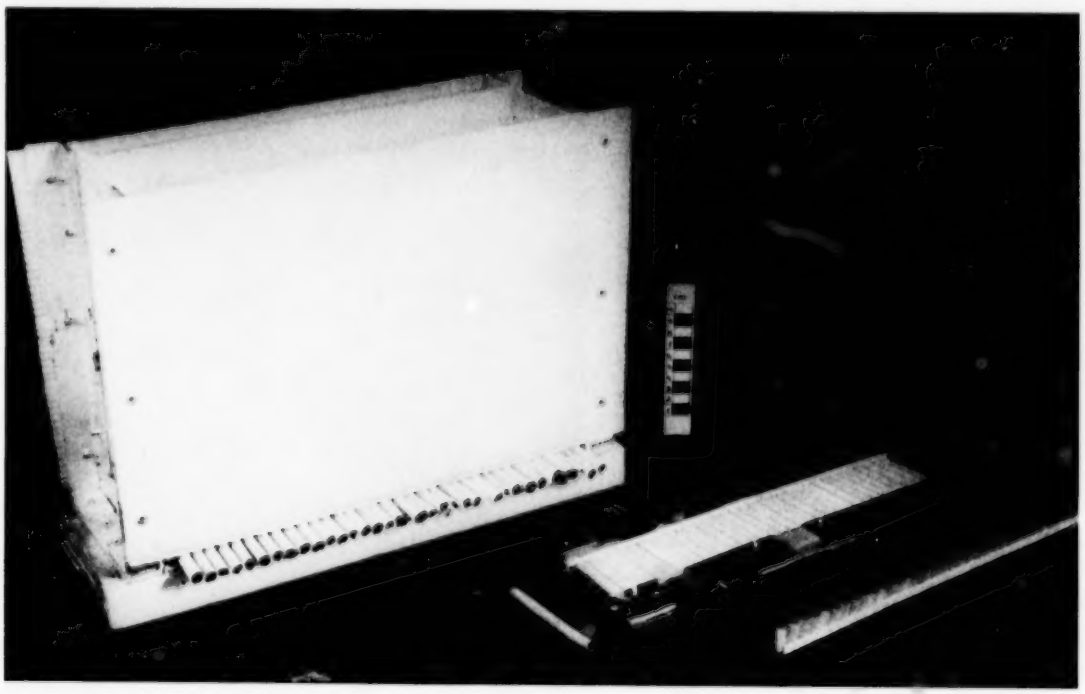

Figure 3 Cutter assembly line for sphagnum cigarettes. Germination plugs are cut in strips to desired length on guillotine paper cutter and seeded by single line vacuum seeder.

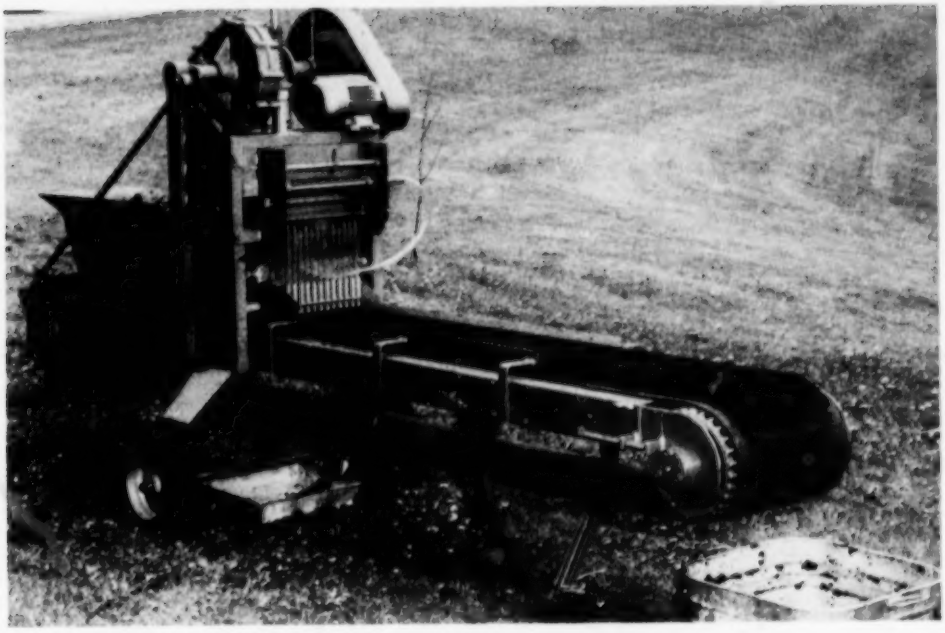

Figure 4 Dewa block machine.

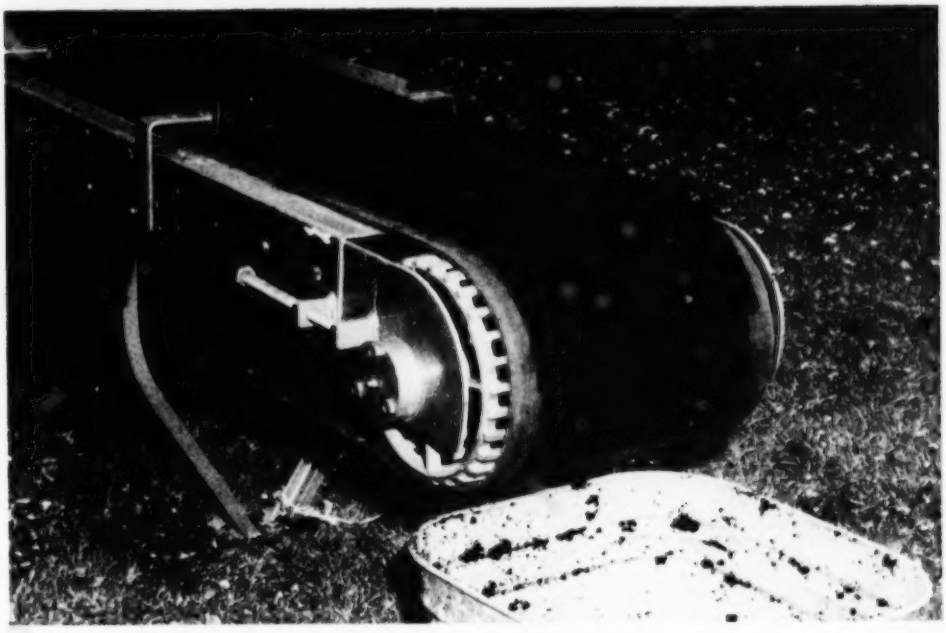

Figure 5 Dewa cubes.

Various greenhouse systems are currently being evaluated. Large heated greenhouses such as those used in Swastika and Thunder Bay have many advantages. They can be loaded during winter months though they are expensive to operate at that time. The 'Finn' greenhouses in use at Swastika utilizing supplemental heat to prevent freezing conditions for seedlings growing in a bed of peat can be loaded early in April. Seedbed shelters (Williamson 1977) of insulated plastic can be established in regular transplant compartments. Without supplemental heat, however, growth initiation must be delayed until danger of severe frost is reduced. Current study proposals include comparisons of the three growing methods.

Transplanting Equipment

Transplanting has been done manually with seedlings rooted in peat cubes being placed in trenches across the nursery bed. No mechanized process has been developed but the potential for automation appears good. Soil cubes of a standard size and shape provide good protection for delicate young root systems, thereby minimizing the risk of damage due to handling procedures.

PROCEDURES

Initial work on the project concentrated on black spruce because seed efficiency is lowest for that species. Developmental and early research work were conducted at Maple and transplants were grown at the Orono provincial tree nursery.

Development of germination plugs, cut from sphagnum moss cigarettes, has been described earlier. The plastic foam plates loaded with plugs were floated on water until the upper surface of each plug was moist. Plugs were sown with single untreated seeds. The procedure was repeated at more or less monthly intervals starting in mid-February, 1975, though limited assistance restricted the number of germinants produced at various times of sowing. Each plug was covered with a thin layer of white commercial silica. Plates were then resoaked, placed in trays sealed in plastic to maintain humidity and put in the greenhouse. Seed was germinated in the greenhouse, as earlier tests had indicated that more rapid germination and taller, straighter more vigorous germinants could be produced than under laboratory conditions or in germination cabinets. Germination conditions were maintained close to the optimum as recommended by Fraser (1970).

As germinants developed and dropped their seed coats, stocked plugs were planted in Dewa blocks of peat from Dunmore bog near Kirkland Lake, Ontario. At this time radicles had developed to the bottom of the plug. For a manual operation, curved-tip forceps were found to be most effective for handling the plugs and enclosed radicles. Trays designed for use with Japanese paper pots were used, having a capacity of 432 peat cubes. After planting, cubes were covered with white silica, filling in any gaps around the plugs, to prevent excessive surface drying.

Trays of germinants were placed in the greenhouse at each planting date and grown until early June. Temperature was maintained at 23°C and humidity at 50%. Trees were irrigated weekly from below. Cubes were soaked until the top surface of each cube was moist and excess moisture then drained from the trays. A standard commercial fertilizer (RX 15) was added with irrigation every second week.

Trees which were sown between February 15 and May 15 were moved to Orono nursery and placed under shades in early June for manual transplanting in the third week in June. Trees sown at later dates were similarly transplanted in early August. Seedlings were sown in marked plots so as to maintain their tray identity throughout the study. In the nursery the trees received the regular nursery treatment for bare root spruce transplants for the duration of the production period.

Each plot was sampled in October, 1975 at the end of the first year and in November, 1976 after two years growth. One row (approximately 20 to 30 trees) was sampled from each plot. Plots were grouped according to the number of trays sown on an individual date or within a narrow time frame of 2 or 3 days, resulting in uneven sampling through sowing times. Top length and root collar diameter were measured for each tree. Roots and shoots of each tree sample were oven dried and weighed to determine a mean dry weight per tree. Shoot/root ratios were calculated from dry weight of top and root materials.

RESULTS

Mean oven dry weight of transplants at the end of the first growing season (Fig. 6) varied directly with number of days since sowing (r=0.876). Similarly dry weight of 2-year-old transplants (Fig. 7) varied directly with duration of growth (r=0.851). The difference in size of transplants relative to time of sowing is illustrated in Fig. 8.

Considerable variation in early seedling size between trays sown on the same date was noted and appeared to be related to position within the greenhouse. Proximity to interior walls or open windows affected air

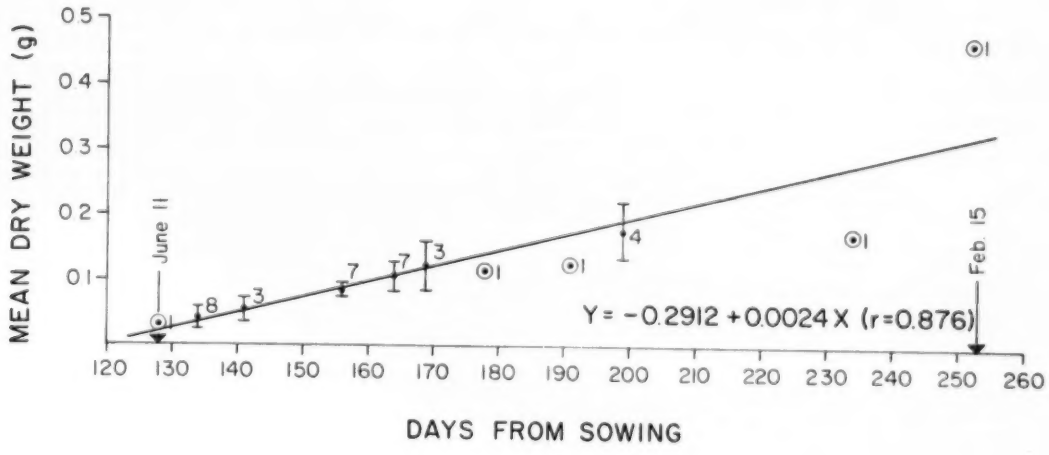

Figure 6 Total oven dry weight of 1-year-old transplants relative to duration of growth since sowing. Numerals indicate number of plots on which means are based. Vertical bars represent one standard deviation in the means of these samples. (See also Table 2.)

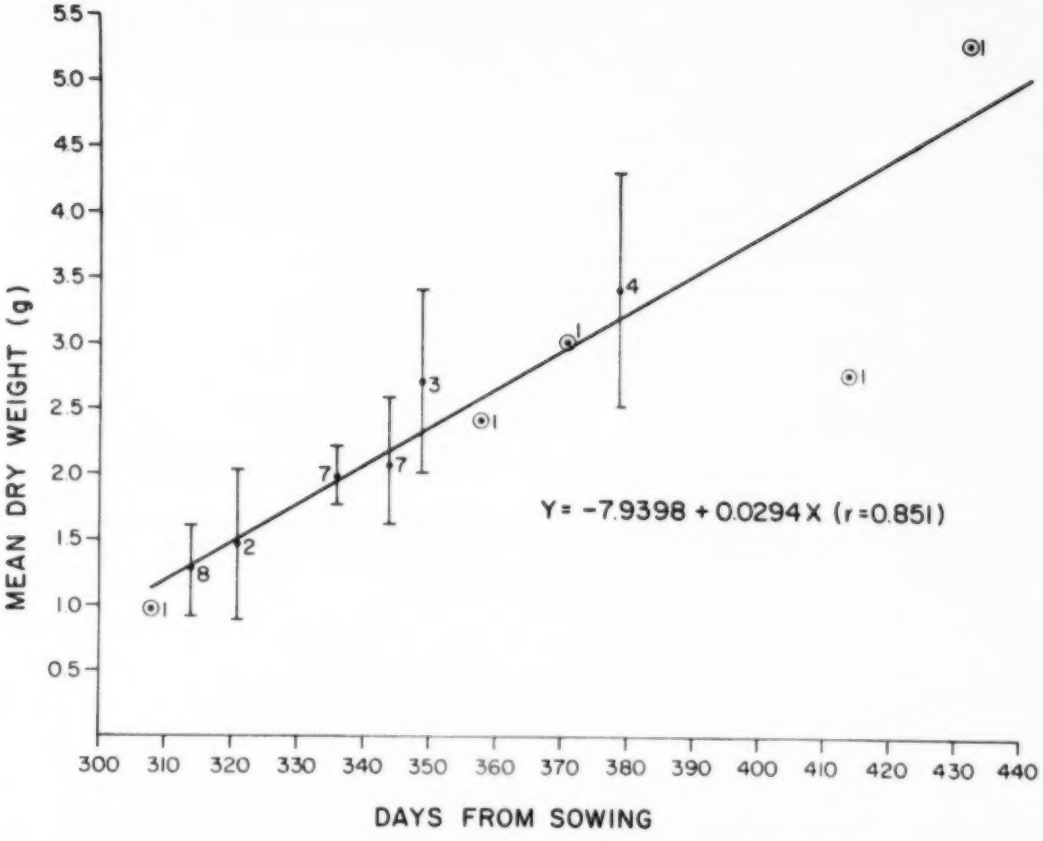

Figure 7 Total oven dried weight of 2-year-old transplants relative to duration of growth since sowing (i.e. first year growing season plus 180 days). Numerals indicate number of plots on which means are based. Vertical bars represent one standard deviation in the means of these samples. (See also Table 3.)

movement, hence soil moisture. Some of the variation in size indicated in Figs. 6 and 7 may be attributable to these uneven environmental conditions during the initial plant establishment stage in the greenhouse.

Current production plans indicate that in the future most bare root black spruce stock will be shipped as 1+2 transplants. Germinant transplants sown prior to May 1 produced 2-year-old transplants with mean heights and root collar diameters (Table 3) in excess of minimum culling standards of 15-24 cm in height and 3.6-4.4 mm diameter for heavy grade, small 1+2 transplants (Reese and Sadreika 1979). However, only black spruce sown in February attained the minimum dry weight of 5.0-6.9 g.

The germinant transplants produced in this study exceed minimum culling

TABLE 2 Assessment of 1-year-old trees, October 1975

No. plots	Sowing date	Mean root collar diam. (mm)	Mean height (cm)	Mean oven dried weight			Shoot/ root ratio*
				Top (g)	Root (g)	Total (g)	
1	Feb 15	1.8	8.7	0.29	0.18	0.47	1.6
1	Mar 2	1.3	5.3	0.12	0.06	0.18	2.0
4	Apr 1/2	1.2	5.4	0.12	0.06	0.18	2.2
1	Apr 9	1.1	3.6	0.08	0.04	0.12	2.0
1	Apr 22	1.0	3.8	0.08	0.04	0.12	2.2
3	May 1	0.9	3.8	0.08	0.04	0.12	1.8
7	May 5/7	0.8	3.7	0.07	0.04	0.11	1.7
7	May 13/15	0.8	3.5	0.05	0.03	0.08	1.9
3	May 27	0.7	3.0	0.04	0.02	0.06	2.1
8	June 4/7	0.6	2.8	0.03	0.02	0.05	1.9
1	June 11	0.5	2.4	0.02	0.01	0.03	1.6

*Based on oven dried weight prior to rounding off data

TABLE 3 Assessment of 2-year-old trees, November 1976

No. plots	Sowing date	Mean root collar diam. (mm)	Mean height (cm)	Mean oven dried weight			Shoot/ root ratio*
				Top (g)	Root (g)	Total (g)	
1	Feb 15	4.7	26.9	3.59	1.74	5.33	2.1
1	Mar 2	4.0	18.3	1.84	0.96	2.80	1.9
4	Apr 1/2	4.0	21.4	2.26	1.13	3.39	2.0
1	Apr 9	4.4	19.9	2.05	0.98	3.03	2.1
1	Apr 22	3.8	17.9	1.65	0.77	2.42	2.2
3	May 1	3.7	19.4	1.80	0.88	2.68	2.0
7	May 5/7	3.5	18.1	1.40	0.66	2.06	2.1
7	May 13/15	3.3	16.2	1.34	0.67	2.01	2.0
2	May 27	2.7	13.3	0.97	0.42	1.39	2.3
8	June 4/7	2.5	12.4	0.86	0.43	1.29	2.0
1	June 11	2.5	12.0	0.65	0.31	0.97	2.1

*Based on oven dried weight prior to rounding off data

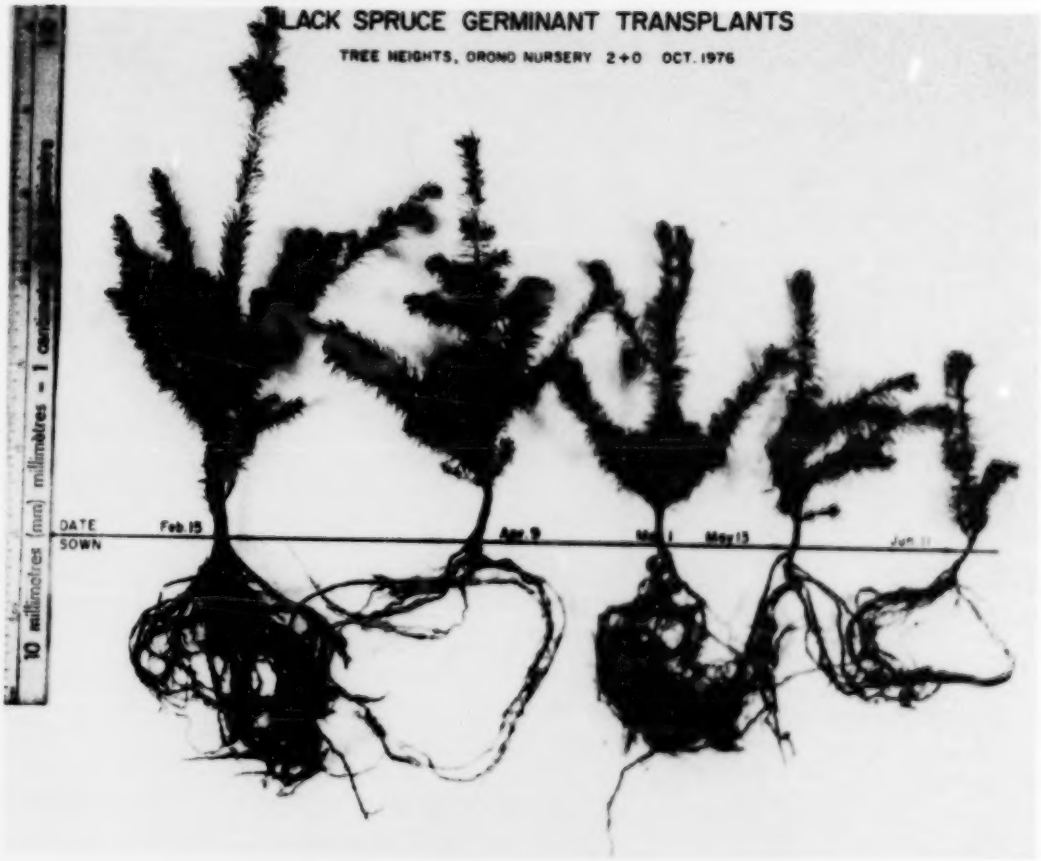

Figure 8 Black spruce germinant transplants in November 1976 related to date of sowing in 1975.

standards of 15 cm height and 3.6 mm root collar diameter set for 3+0 stock (OMNR For. Man. Br. Internal Memo). Armson and Carman (1961) recommended 3.0-4.0 g total dry weight for large 3+0 and over 4.0 g for very large stock.

Data for other transplant products are provided by Armson and Carman (1961). Medium, large and very large classes of 2+1 black spruce are expected to fit in the ranges 2.0-3.0 g, 3.0-4.0 g and over 4.0 g oven dry weight respectively. Comparable data for 2+2 black spruce are 8.0-10.0 g, 10.0-12.0 g and over 12.0 g. It is apparent that the 2-year-old germinant transplants sown up to May 1 are at least comparable to large 2+1 stock but far below expected size of 2+2 transplants.

For the germinant transplant system to produce the 2-year-old size shown in this study, a plant 3.8 cm tall, 0.9 mm in diameter and 0.12 g oven dry weight is required in the first year (from Table 2). However, it appears that a plant of 0.4-0.5 g oven dry weight would be necessary in the first year to produce a 5.0 g transplant at the end of the second year.

The stock in all samples was well balanced. Shoot/root ratios ranged from 1.6 to 2.2 in the first year (Table 2) and from 1.9 to 2.3 in the second year samples based on oven dry weight of roots and tops (Table 3). These are well below the maxima of 4.5 and 3.0 recommended by Armson and Carman (1961) for 3+0 and 2+2 stock respectively, and the 2.5 maximum for 2+1 stock recommended by Armson and Sadreika (1974).

DISCUSSION AND CONCLUSIONS

Time of sowing has a strong influence on 2-year-old plant size (Figs. 7 and 8). All trees grown from seed sown up to May 15 experienced two full growing seasons in the nursery, the only difference being the extent to which plants developed in the greenhouse prior to transplanting. Absolute differences were not great at time of transplanting, yet initial plant size at the start of the season had a proportional effect in subsequent growth over the following two seasons. No doubt similar differences occur in seedbeds as a result of variable germination times, affecting stock uniformity and culling costs at time of shipping.

The influence of early initiation of germination on first year growth is apparent in photographs of the different stages of development of germinant transplants compared to average 1+0 black spruce from seedbeds of a southern nursery (Fig. 9). The latter averaged 2.0 cm less than the height of seedlings after 2 months in the greenhouse and were negligible when compared to the one-year-old transplant.

Plants from seed sown by May 1 attained minimum height and root collar diameter standards. This suggests the possibility of using unheated greenhouses or protected nursery beds rather than more expensive heated greenhouses. With less costly space, lower densities might be feasible in the first production phase. Eventually, determination of the size and number of soil cubes in the trays in the greenhouse must be related to costs affected by seedling yields, and to transplanting practices in the nursery (e.g. number and spacing of rows in transplant beds, spacing within rows).

Though duration of growing season accounted for 76.8% of the variation in mean dry weight production in the first year and 72.4% in the second, there was also considerable early variability between trays in the greenhouse. This variability showed the importance of growing conditions early in the production schedule if uniform stock is to be produced because environmental effects were magnified through the duration of growth. Optimum conditions must be established for early stages of production and applied uniformly across the greenhouse.

A major value in using a pregermination process is in stock production systems using valuable genetically improved seed lots initiated in controlled environments. Greenhouse transplants and containers are two such systems expected to represent a high proportion of future production plans (Scarratt and Reese 1976). Black spruce, though representing major establishment problems in seedbeds, germinates well under optimum conditions because of the germinative characteristics of the species. Using seed pregerminated under optimum conditions, high seed efficiency rates are achieved, greenhouses are operated at close to full capacity and seedlings are all at a

Figure 9 Three-week-old germinant in plug ready for planting (extreme left) and after two months growth in peat plug prior to transplanting (centre left). A one-year-old greenhouse transplant is shown (centre right) in comparison with a nursery-run 1+0 seedling (extreme right).

similar stage of development resulting in a high degree of stock uniformity at time of transplanting.

Few losses are expected following transplanting and since seedlings are transplanted in their rooting medium with little root disturbance, the final result is precision grown stock. Bunting (1973) has shown that bed density is a major factor in plant development. With uniform spacing, plants develop at comparable rates, resulting in bed-run shippable trees without significant culling costs. The resulting reduction in growing time, to two years with black spruce, will allow the nursery staff to produce greater annual yields of plants on the same area of nursery beds. The reduced production period will also facilitate the planning process, allowing nurseries essential flexibility in meeting district targets.

Mechanization is the key to practicality. Concepts for complete automation from germination to transplanting (Skeates and Williamson 1979) have been prepared. Work is continuing on the development of each step, i.e. production of germination plugs, planting of germinants, loading pallets of stocked cubes, and transplanting of 'cubed' seedlings. Research is continuing on the use of pregermination techniques with seed of other species having more difficult germinative characteristics.

This study has shown that a system of growing shippable 2-year-old transplant black spruce is possible. The stock is comparable to the 3-year-old plants grown either as 3+0 seedlings or small, heavy grade 1+2 transplants. The germinant transplant system, starting with seed pregerminated under optimum conditions, planted in peat cubes under greenhouse conditions and transplanted in standard transplant beds, has potential value in the provincial stock production program.

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